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ABSTRACT

The common links in language learning theory relating to school content areas are the notion of input comprehensible to the learner, the distinction between language usage and use, and the concept of cognitive/academic language proficiency in contrast with basic interpersonal communication skills. This suggests that a laboratory-based science class using an inquiry approach would be an optimal source of comprehensible input and communicative use of language, drawing on and contributing to further development of cognitive/academic language proficiency. A study of the acquisition of English as a second language by a native speaker of Gujarati in the context of a high school physical science course during one academic year provides evidence of enhanced language learning. The student was tested for English language proficiency and language attitudes in September and May of the school year, and other materials such as personal letters to the teacher and lab reports were examined for language usage and grammar. The data show that in the course of the year the student moved out of pre-production English and systematically and extensively acquired linguistic forms for both personal and technical writing even though the teacher did not direct overt attention to language forms and the mechanics of written English. The results support the idea that a lab-based science facilitates development of both spoken and written language. (MSE)

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SECOND LANGUAGE ACQUISITION IN THE CONTEXT OF SCIENCE EXPERIENCES

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Language is best taught
when it is used to transmute messages
not when it is explicitly taught
for conscious learning.
(Krashen & Terrell, 1983:55)

The view of second language acquisition articulated in current theory points to the critical role of the school content area for the successful development of a second language. This theory applies to learners of any age engaged in aspects of the schooling process, from primary school basic instruction to secondary school subject matter and college or university-level specialized education. The common link in all aspects of utilization of the school content area is the key notion of input comprehensible to the learner (Krashen, 1982), the distinction between language usage and use (Widdowson, 1978), and the concept of cognitive/academic language proficiency in contrast with basic interpersonal communication skills (Cummins 1981, 1983). It is against these notions that, within the school content areas, a laboratory-based science class utilizing an inquiry approach would appear to be among optimal sources of comprehensible input, communicative use of language drawing on and contributing to further development of cognitive/academic language proficiency.

This paper reports findings on the acquisition of English as a second language by a first-language speaker of Gujarati in the context of a high school physical science class. In a longitudinal study conducted over an academic year during which the student progressed from a beginning to intermediate level of English proficiency, particular attention is given to the analysis of science laboratory reports as indicators of language development and the acquisition of second language literacy. Evidence is presented that the interactive nature of science

laboratory work, providing a source of comprehensible and relevant input, appears to facilitate development of proficiency in a second language.

Science experiences allow second language learners the opportunity to draw on concepts they already know while at the same time providing sources of genuine language use. This relates to Widdowson's (1978) distinction between language usage and language use. Usage is that aspect of linguistic performance which manifests knowledge of the rules for the language system. Demonstration of a linguistic structure may not, however, be an instance of using language communicatively. Realization of language as use involves both usage, the ability to select appropriate forms for a particular linguistic context, and the ability to draw on rules governing meaningful, effective communication for situational contexts. Knowing a language includes knowledge of language usage but, additionally, includes knowledge of rules for the discourse functioning of language. Knowing language usage does not guarantee knowing how to use language. Learning to use language, however, does seem to lead to the development of language usage. In other words, presenting a second language in a discourse context with focus on the communicative functions of language directs development of that language in its entirety, usage and use.

Achieving the development of language use, or discourse, can perhaps most effectively be realized in the school setting by relating the teaching of a second language to the content areas of the school curriculum. In this way, the teacher can tap the student's prior knowledge, build on it while at the same time leading the student to a realization of that knowledge in a new language system. Clearly, discourse cannot be taught in isolation, but only when it involves genuine language use. Those areas of language use most accessible to language teachers and learners in the school setting are those of the content areas of the school

curriculum. School subjects provide, by their very nature, the kind of input that serves as a rich source of the structures and conventions needed to understand the basic concepts and procedures of the content dealt with.

Science would appear to offer a particularly fruitful source of input for the language learner. For a secondary school student with earlier experience in elements of science instruction, the basic types of scientific discourse may already be familiar: descriptions, reports, instructions for lab procedures, accounts of experiments, statements of conclusions, and generalizations. Realization of these discourse forms in a new language is to draw on certain reasoning processes basic to the discipline regardless of the language of expression. For students not familiar with such discourse uses of language, however, the types of texts and lab manuals characteristic of science education programs presents these aspects of scientific discourse in clear, comprehensible styles. Extensive utilization of graphics, definitions of new terms, utilization of fairly straightforward language structures, explicit and easy to understand directions for carrying out lab procedures contribute to the transmission of meaning. This type of input corresponds closely to Krashen's (1982) view of optimal input - comprehensible, meaningful, and relevant to the language learner. The pictures, diagrams, and other types of visuals typically found in science texts and manuals supply the extra-linguistic context that helps the student to understand and acquire the language. The vocabulary often new to native speakers as well as second language learners is frequently given with a definition or a visual, all of which contribute to fuller comprehension of the material and heightened opportunity to acquire the terms and associated language forms. Successful science instruction draws extensively on multiple devices, linguistic and extra-linguistic, to insure student comprehension. Effective science teaching, in other words, sets up the language learner, or acquirer to be more precise, for receiving the type of input

necessary for language acquisition, the natural, subconscious process which occurs when language is used for genuine communication. As Krashen (1982) argues, language acquisition is the process central to the development of a second language. It contrasts with language learning, the process for developing a conscious, explicit knowledge of language forms. This formal knowledge of the linguistic rules of a language corresponds to the notion of language usage, knowledge of a language system that may be present without the knowledge necessary for language use. Development of language use may be seen as resting on the process of language acquisition.

In addition to the science teacher or the texts and lab manuals as sources of input, the interaction of the language acquirer with peers who are native speakers of the second language also serves to generate input. In the discourse interaction typical of a science lab, language functions observable in language use include a wide range such as requesting, informing, seeking clarifications, making observations. The interaction that occurs between partners in a science lab experience is one of genuine language use, focused on the following of directions, carrying out the procedures, drawing conclusions. The small group activities of a lab-based science class provide opportunities for discourse interaction with peers. This contributes in particular to the development of the spoken language, both listening and speaking. Participants make use of both aural and visual media, including linguistic, paralinguistics, and extra-linguistic phenomena.

Science experiences provide the potential for integration of all modalities of language use, not only the spoken language but also the written language. Reading the text, following directions in the lab manual, and writing the report of the science investigation carried out in class provide opportunities for the development of second language literacy, reading and writing. Although clearly

different in terms of reception and production, reading and writing make use of the visual medium of written language to create or re-create a discourse in the mind by a process of reasoning. Sources of comprehensible input to the language acquirer may then be both spoken and written language. The effort to use either contributes to the acquisition of competence in a second language.

Although an adequate theoretical framework for language proficiency is still lacking, recent work by Cummins (1981, 1983) has contributed to further understanding of the type of language proficiency necessary for school success. By integrating the notions of contextual support and cognitive involvement in language use, Cummins distinguishes two major continuums, which interact in language development and in language use. On the context support continuum, context-embedded tasks which allow for active negotiation of meaning, such as partners may carry out in the spoken language during lab experiments, are distinguished from the more context-reduced tasks which require greater reliance on linguistic cues and on the propositional and logical structure of the information involved. Examples of such tasks relate to those drawing directly on the lab manual directions and the science text itself. Cognitive involvement, to follow Cummins' definition (1983,121), "can be conceptualized in terms of the amount of information that must be processed simultaneously or in close succession by the individual in order to carry out the activity." Active participation in science lab experiences, engaging in the problem-solving activities presented, draws on active cognitive involvement leading to the development of the type of cognitive/academic language proficiency that Cummins argues is essential for academic achievement. Lab experiences with the opportunity to negotiate meaning orally while following the written directions leading, ultimately, to the culminating activity of writing a lab report draw on both context-embedded and context-reduced language activities. By their nature, these experiences engage extensive

cognitive involvement processes.

This view of language proficiency may also be related to the general framework for language use or communicative competence proposed by Canale (1983a). The main components in Canale's model include: (1) grammatical competence or mastery of the language code; (2) sociolinguistic competence or mastery of the appropriate use of language in differing social contexts; (3) discourse competence or mastery of rules for combining and interpreting meanings and forms to achieve a unified whole; (4) strategic competence or mastery of strategies to compensate for breakdowns in communication or to achieve a rhetorical effect. Science experiences provide the input for development of each of the components. The grammatical system, usage, develops along with use in the sociolinguistic contexts appropriate to school, in the opportunities to develop strategic competence and in the interactive discourse structuring of the science problem-solving activity. Current theory supports the expectation that students acquiring a second language will develop proficiency in that language in the context of science laboratory-based experiences. It is, of course, important to keep in mind, as Canale (1983b, 342) cautions, that "language proficiency is only one of many complex and little understood cognitive systems that interact in performance of any language task."

Literacy involves communicative competence in the written language, mastery of the functions of reading and writing and the forms necessary to express them. For the acquisition of second language literacy, literacy in a first language is a major asset. As Cummins argues, if the cognitive/academic language proficiency necessary for reading and writing is developed in the first language, it is accessible for second language use once the linguistic code is available. Acquisition of second language literacy then requires the development of the second language system with a wide range of form-function relationships. It is, as

Smith (1978) points out, acquired most effectively when attached to one's own experiences or goals. More important than materials and curricula designed specifically for teaching literacy are opportunities for significant interactive relationships with others literate in the language. Reading and writing in communicative exchanges lead to development of these modalities, just as listening and speaking do for that of the spoken language. One basic necessity for learning to read is the availability of interesting material that makes sense to the learner (Smith, 1978). In other words, the learner must have relevant, comprehensible input. The other necessity is having an understanding guide for the second language situation. This may be a teacher or it may be peers. It must be someone who knows how to read the language and can interact to help the learner make sense of the printed page.

Literacy does not draw on a language system different from that used in the spoken language. Once the system is acquired it is potentially available for all modalities: listening, speaking, reading, and writing. Language acquired through science experiences, then, becomes available to second language literacy. In addition to acquisition of the language, however, is acquisition of the rules governing the mechanics of the written language: capitalization, punctuation, and spelling conventions. If science experiences facilitate the development of the language system, one may also hypothesize that they will facilitate the development of the mechanics of the written language if utilized effectively.

To test the hypothesis that science experiences promote second language acquisition and development of second language literacy, a longitudinal study was conducted over an academic year for a first-language speaker of Gujarati enrolled in a high school in San Antonio, Texas. Particular focus is given to cognitive/

academic language performance manifested in written reports of science laboratory experiments conducted in a physical science class in which he was enrolled.

Subject

The subject for this study came to Texas at age 16 from Gujarat, India, a state in the west central part of the country. His first language was Gujarati, an Indic language spoken in Gujarat and neighboring regions in western India. Although he had had 12 years of schooling in India, he had no prior study of English other than for a short time as a very young child in the primary school, and then for only a few minutes a day. As a result, he tested at a zero level of English proficiency on enrolling in a high school in San Antonio, Texas, where he expected to earn a high school diploma before undertaking studies to become an engineer. He came to the United States on immigrant status with his parents, who joined other relatives in Texas to continue the father's occupation in business. Perhaps related to his engineering interests was his identification of math and science as favorite school subjects.

Since he entered a U.S. high school with no proficiency in English and no familiarity with the English writing system, he spent the first year in ESL classes along with auditing math and other less verbally-based courses. Judging from teacher observations, he remained principally at a pre-production or 'silent period' stage of English language development during the first year. This study follows the productive development of English as a second language in the context of a science class during his second year in the same school.

Scores in percentiles on the Secondary Level English Proficiency (SLEP) Test at the start of this study are given on Table 1.

Table 1. Secondary Level English Proficiency (SLEP) Test Scores in Percentiles

ADMINISTRATION	LISTENING	READING	TOTAL
September, 1981	26	29	28
May, 1982	51	48	52

SLEP scores indicate extensive development in English proficiency during the second year, a change from beginning to intermediate level of proficiency.

Along with the standardized language proficiency test, a language use/attitude questionnaire was administered at both periods in order to gain insight into factors that might affect the affective filter (Dulay, Burt, and Krashen, 1982). The subject was asked to assess the same factors, first after one year of schooling in the U.S. and again after completing a second academic year in a U.S. high school.

After one year, the subject stated that he continued to use Gujarati with his parents and siblings and that he used it in thinking about problems in his life. At the end of the second year, he claimed to use English with siblings, possibly because his sister had married an American. In both surveys, he saw English as the language most useful for his future although he expressed a desire for his own children to be bilingual in both English and Gujarati when he married.

Attitudinally, on both surveys he indicated that he wanted to understand Americans very much. At the end of the first year, however, he felt he should think and act like Americans but by the end of the second year, he had changed considerably, feeling that this was only minimally necessary. During the same time he had changed in feeling free to ask help in classes from often to only occasionally. At both periods he found U.S. students only moderately friendly. Nevertheless, he felt less criticism of his English at the end of the second year than at the end of the first. Although his long range preference for country of

residence after completing college was the United States, his immediate preference changed from the U.S. at the end of the first year to dividing time between the U.S. and India at the end of the second year, a possible manifestation of aspects of culture shock. Along with this was the admission of writing letters very often to India by the end of the second year but never writing any during the first year.

In summary, the first language continued to be maintained basically as the language of the home and outside of school since most interactions during both years were with Gujarati-speaking relatives. Attitudes shifted somewhat from an original position of wanting to assimilate to American culture to desiring to preserve more of the first language and culture. While he felt more confident in using English, he felt less comfortable in seeking help from teachers and fellow students, maintaining a consistent view that U.S. students are only moderately friendly. While it is not possible to assign a quantitative value to the affective filter, qualitatively it appears that some of the factors would interact to inhibit or at least slow down the second language acquisition process.

At the start of the second academic year in Texas, the subject enrolled in a ninth grade physical science class taught by the same teacher in whose ESL class he was also enrolled. Data from these two classes serve as the basis for this study.

Procedure

Data for this study are 20 laboratory reports collected in a physical science class at regular intervals over an academic year. For the purpose of analysis, these are grouped into four sets to correspond with the four academic grading periods for the year. There are five reports for each academic quarter. The written data provide a source for analyzing the development of form-function relationships associated with science, with emphasis on following written directions identifying materials, describing procedures, making observations, stating hypotheses, and drawing conclusions. In addition to this focus on the language

system, the acquisition of handwriting and the mechanics of written English are examined to gain insight into aspects of the acquisition of English literacy. Specific attention is given to the development of spelling, punctuation, and capitalization. Findings from the science data are also examined in the light of data collected over the same period in an English as a second language class, a period in which the student progressed from beginning to intermediate levels of English proficiency.

The science reports follow a form prescribed by the teacher for listing the title of the science experiment as given in the text, the problem as synthesized by the student, the materials as listed in the directions, the procedure as summarized from the more detailed version in the text, the presentation of findings or observations as determined by the actual lab experience, and the conclusion drawn by the student from the data gathered in the science activity. The written report was a required follow-up to all experiments conducted in the class.

With this format, science reports typically generated language that, for some portions, was copied from the text and, for other portions, was produced creatively by the student. This distinction is taken into account in the analysis of the data by matching reports with the original text, counting the number of words copied directly and counting those generated productively. Ratios were then established for the number of errors to the total number of words copied on the one hand and the number of errors to the total number of words creatively generated on the other hand. Categories of errors counted included the errors in form for assessment of proficiency in the language system and errors in spelling, punctuation, and capitalization for assessment of acquisition of mechanics in writing.

The language used in the science reports is necessarily highly constrained, directed to a specific set of language functions carried out with respect to a specific topic with its related vocabulary. In order to compare errors found in

lab reports with those found in more informal, personal written exchanges, a set of letters addressed to the ESL teacher as part of a dialogue writing project in the ESL class were analyzed following the same criteria used for the lab reports. Four letters representing the same four periods of the academic year as the science reports provided data for this part of the analyses. The letters permitted learners to choose topics and make selection of vocabulary and structures freely.

Analysis of the Data

Figure 1 gives an overall pattern for the data analyzed in this study, identifying the total number of words generated on the 20 science lab reports and the 4 ESL letters divided over the quarters of the academic year. The subdivision of data from the science reports illustrates the extent of copied data as opposed to production data.

Figure 1. Total words generated in science reports and ESL letters

INSERT FIGURE 1

During the year the student generated increasingly larger amounts of language productively. As this occurred, the extent of copying from the science lab manual began to decrease during the last part of the academic year.

Based on directions found in Bickel, Eigenfeld, and Hogg, Physical Science Investigations (1973, 52) for experiment 3-10, the following example of a science laboratory report represents stage 1, the first quarter of the academic year:

exp. 3-10

Title: The force of friction and the waight of a Body

Babelm: what happned to the force book.

Materials = spring scale; loop of thread; 4 Textbook

Procedure - Four textbook will be needed for this experiment, so should work in groups of four.

Find the weight of book by means of a spring scale, and record the weight

number of book	weigh of Book in newton	Force of (Friction) in Newten
1	9 N	$3\frac{1}{2}$ N
2	18 N	$6\frac{1}{2}$ N
3	27 N	10 N
4	36 N	12 N

Congusenel - the book differce newten and twice time

The student clearly understood and followed the procedures in recording the weights and calculating the force of friction, arriving at a reasonably appropriate conclusion even though verbalization posed a difficult problem. Errors in copying can be seen in absence of the plural marker on textbook, omission of the indefinite article with book and in the mechanics of writing, from spelling errors to capitalization and punctuation. Errors in production are more extensive as seen in the efforts to state the problem and give the conclusion.

During the same time period as the science report, the following personal letter was written to the teacher in an ESL class:

Dear Dr Quim,

I am very pleas with when you explin me. you are very good person hope every day, every time keep that Hwy. Some time I was make noise voice I want sorry aboutt that. If you reyally help me I am sare make good grad. I know you some time help me but they doesn't work. you can't always hepp me that"s true.

In marked contrast to the language functions used for the science report, the personal exchange includes those characteristic of basic interpersonal exchanges: compliment, apology, request, and self-expression functions. A range of errors in form can be observed in the attempts to carry out the functions expressed in this personal letter. Additionally, numerous errors in the mechanics

of the written language are also apparent.

Over the following two academic quarters, both lab reports and the ESL letters became longer. At no time, however, did the teacher correct either the reports or letters for errors of any type. Rather, the teacher's written comments for both types of data were in response to the meaning conveyed, accuracy of the conclusions and supporting data on the science reports and comments of encouragement on the letters.

The ESL class in which the student participated was in large measure an acquisition-rich class in which the students engaged extensively in communicative types of activities rather than in those focusing primarily on language forms. Consequently, increased proficiency in a second language over time can largely be attributed to acquisition rather than learning processes.

Change in the quality of language used in writing science lab reports can be seen in the following report submitted at the end of the academic year, experiment 5-8 in Bickel et al (1973, 137):

Experiment = 5-8

Titals = To Find the Solubility of Sodium Chloride by Evaporating a Saturated Solution

Problem: find solubility of sodium chloride

Materials = 100 ml graduate; evaporating dish; equal-arm balance; stand; 4-inch ring, wire gauze; burner

procedure: 1) find the mass of the evaporating dish, pour the solution into the dish

2) Attach the ring to the stand so that the ring is about 10 cm above the top of the burner

3) When the salt appears to be dry, heat the dish strongly with the full flam of the burner.

data:

1) mass of empty dish	44.2 g
-----------------------	--------

2) mass of dish plus solution	66
3) mass of solution	21.8 g
4) mass dish plus salt	51.4
5) mass of salt	7.2
6) mass of water	14.6
7) volume of water (ml)	14.6
8) solubility of NaCl	49.3

$$\frac{\text{mass of salt (g)}}{\text{volume of water (ml)}} \times 100$$

Congulsen: Salt is very solubility in water.

By this stage the student is paraphrasing and summarizing more extensively rather than relying primarily on copying. Fewer errors are apparent in the forms needed to carry out the various functions called for in writing science reports. Fewer errors in the mechanics of writing are also observable when this stage 4 report is compared with that from stage 1.

The following letter written in the ESL class during the same quarter reflects aspects of considerable language acquisition over the school year when it is contrasted with that of stage 1.

Dear Dr. Quinn,

You know what I was come hear from India. That time English very hard for me because in my country I never use English. Other think is a pronouns differnt than my country. So never contact with my Pronouns.

After two years English language easier than before and past two year I am improved so much. I have not exprince in English leguage so I try hard. Most time I talk with my friends they understand me. They said to me you improviied so much. Well I still not belived. anyway now English more easier than before.

I like English subject. because when I was 5 or 6 years old I went three years English school. I speak litter beat English. Now English legwage more easiar than my leguge because I study in high school. jist seven hour I have to speak English to anybody.

In summary, the lab report and ESL letter written at the beginning of the year appear to relate closely to the student's scores on the Secondary Level of English Proficiency (SLEP) Test found to be at the 28th percentile. The science report and ESL letter at the end of the year correspond to the SLEP score at the 52nd percentile.

Errors in language form observed for the productive language used on the science reports are associated with the functions of stating the problem, giving the directions in summary or paraphrase, stating the findings, and drawing the conclusions. Those observed for the copied data are associated with the functions of stating the title, the materials used, giving directions exactly as stated in the text. The ratios for these two sets of errors are kept separate in Figure 2, which also gives the ratio of errors observed in carrying out the various functions expressed in the ESL letters, ranging from compliments and apologies to self-expression and informing.

Figure 2. Ratio of errors in percent to total words for science reports and ESL letters for academic year

INSERT FIGURE 2

The pattern of errors in the grammatical forms used in realizing various functions suggests that initially the constraints imposed by the type of language

required for writing science experiences presented more difficulty than ESL letters. Letter-writing made possible the utilization of avoidance strategies and the use of linguistic structures in the developmental range of the student. Over the year, however, as proficiency increased both in language and in knowledge of science concepts, this distinction diminished. By the end of the fourth quarter, the student had achieved equal proficiency in both types of writing. He could express the functions of science as easily as those of a more personal nature in the ESL letters. Over time, too, copying material from the science text became increasingly accurate.

Close examination of the errors in form made in the science reports reveals that the categories manifesting the largest percentage of error included omissions of the copula be, prepositions, and articles. Interaction of these omissions resulted in what superficially appears to be errors in word order, as in reaction chemical for reaction of the chemicals and force book for force of the book. When combined with omission of non-referential there and it, a statement such as There is a difference for metals in HCl is rendered as difference metals in HCl. In this product it is insoluble becomes product insoluble. These errors persist to the end of the year but in a diminishing ratio.

Part of the acquisition of literacy in a second language is the development of rules for spelling, punctuation, and capitalization conventions. The latter category is particularly problematic for language learners coming from a literate tradition with a writing system different from that for English. The system used for writing Gujarati differs radically from that for English in form although not in directionality.

Handwriting problems such as those focusing on upper and lower case distinctions continued to pose difficulty for the student during the entire year,

as indicated in Figure 3 showing errors in capitalization

Figure 3. Acquisition of rules for capitalization

INSERT FIGURE 3

The pattern indicates the ratio of errors in capitalization to the total number of potential capital letters. The extensive difficulty the student experienced at the beginning of the year in forming capital letters decreases over time, but continues to remain high. A particularly problematic letter was capital P, which had high frequency in the productive portions of the science reports such as in the use of the word percentage or potassium. The ambivalence in capitalizing can be seen in the following alternations for the subtitle Procedure required on the reports. The fluctuation over the four academic quarters, stages 1 through 4, can be observed in the following pattern: (1) procedure --> Procedure; (2) Procedure --> procedure; (3) procedure --> Procedure; (4) Procedure --> procedure.

Punctuation errors were calculated in terms of the total potential for punctuation marks of all types: commas, periods, colons, semi-colons, and apostrophe marks. Figure 4 illustrates the gradual acquisition of these writing conventions.

Figure 4. Acquisition of punctuation conventions

INSERT FIGURE 4

The gradual decrease in errors over the four quarters basically reflects an acquisition process since the science/ESL teacher did not correct written material for punctuation. The process of acquisition can be observed in the salutation for the ESL letters for each of the four quarters, or stages: (1) Dear Dr Quim. becomes (2) Dear Dr. Quim and later for stage (3) Dear Dr. Quinn. followed by (4) Dear Dr. Quinn, in the last letter at the end of the year.

Literacy in English requires adherence to complex rules for spelling. Figure 5 gives the general pattern observed for the acquisition of spelling conventions, showing the relationship between spelling errors and the total number of words in each type of data.

Figure 5. Acquisition of spelling conventions

INSERT FIGURE 5

The most extensive decline in spelling errors occurs in the self-generated productive portion of the science reports between the first and third quarters. Little revision of spelling rules occurs during the last portion of the year. Variation can be seen in the word Title required on all science reports. Stage (1) shows Tital --> Title, which changes in stage (2) when, at first Title --> Titils and, later, Titils --> Titals towards the end of the quarter. Stages (3) and (4) remain Titals. A spelling error such as this may be intersecting with a semantic feature marking for the noun title. Rather than considering the semantic meaning of title as a label for the group of words that make up a title, the learner may be assigning the meaning that it applies to each item in the title. This would account for the persistent plural -s marker. The other error

in spelling title as tital reflects accurate pronunciation and a regularization of English spelling rules.

In summary, during the second year of schooling in the United States, the subject moved out of the pre-production phase for English as a second language. The acquisition of linguistic forms necessary to carry out functions for written reports of science experiences as well as those for personal letters developed extensively and systematically during the second year of enrollment in an English-speaking high school. Even though the teacher did not direct overt attention to language forms and to the mechanics of written English, development occurred in each area.

Discussion

The extent of second language development evidenced by the ESL learner studied in the context of a laboratory-based science class suggests an optimal role for science in the second language acquisition process. Science experiences provide a source of cognitive conflict for the learner. To follow Piaget's (1970) theory, the resolution of this conflict leads to further cognitive development. In Cummins' view, this embraces the cognitive involvement that must be present for language to develop. Among studies reporting the positive effects of cognitive conflict on second language acquisition is that by Kessler and Quinn (1982). In Krashen's theory, focus on the meaningful use of language is requisite to language acquisition processes. Science experiences in the school curriculum provide a source of genuine language use, meaningful and relevant to the student. The input provided in these activities is comprehensible, drawing on concepts that the learner already has developed through the first language and engaging aspects of cognitive/academic language proficiency available from the first language. Furthermore, the language in science texts is relatively constrained with specific structures and vocabulary recurring with considerable redundancy. This type of

control on input and the ready availability of visuals, diagrams, and charts contribute to the clarification of meaning. Additionally, the frequent opportunity for peer interaction to negotiate meaning and discuss observations, hypotheses, and test results contribute to the comprehensibility of the input. Meanwhile, science experiences often generate high interest in the task, encouraged by active involvement in the procedures. This in turn relates to a low affective filter, contributing positively to the language acquisition process.

If language may be defined as "doing things with words with people" (Edmonds, 1981, 2), science provides a rich source of language used to do things with people, of realization of the discourse functions of language. Science activities provide experience with a wide range of language functions, from exchanging information, directing, questioning, clarifying, expressing ideas, requesting, stating conclusions. The clear focus of the activity and the availability of language forms for carrying out dimensions of these functions through directions given in the text enable the language learner to participate actively in the experience.

A lab-based science course facilitates development of both the spoken and written language. Working in small groups makes possible the type of discourse interaction with peers that facilitates development of the spoken language, listening and speaking. Reading the text, following directions and writing a report of the activity further the development of literacy, reading and writing. The integration of all modalities of language use in a science class is a characteristic that argues favorably for the optimal role of science experiences in the development of bilingualism and biliteracy.

As the language system develops and becomes available to both spoken and written language, the mechanics of capitalization, punctuation, and spelling also are acquired in the context of trying to use them to write reports of the scientific activity. The literacy tasks are based on language the learner understands and

can use, ranging from expressing the problem under investigation, paraphrasing and creatively expressing the procedures followed, stating findings and test results, and formulating hypotheses or drawing conclusions.

Findings from this study suggest that science experiences provide a rich source of conditions for promoting the acquisition of a second language, along with its manifestation in the written language. The type of cognitive/academic language proficiency required for content areas in the school curriculum conjoined with opportunities for basic interpersonal exchanges such as those found in personal letter-writing provide the kind of input that triggers natural language acquisition processes. The extensive progress made by the second language acquirer in this study may, at least in part, be reflective of the optimal second language acquisition conditions provided in a lab-based science class. The positive effects of science experiences on second language development give further evidence that language is best taught when there is no direct, overt attempt to teach it. Language most effectively develops when it is used to transmit the messages that are the functions of language.

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FIGURE 1

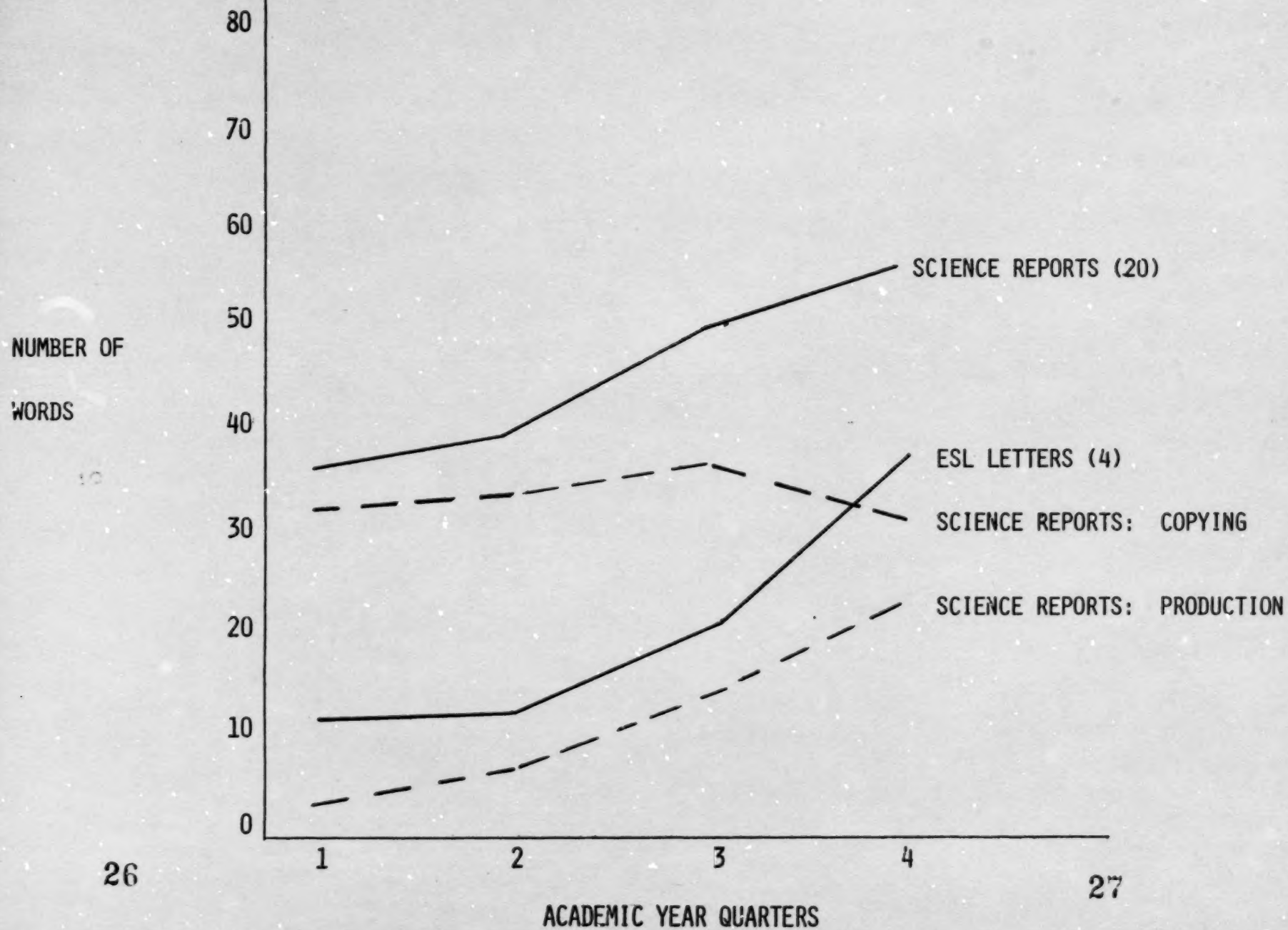


FIGURE 2

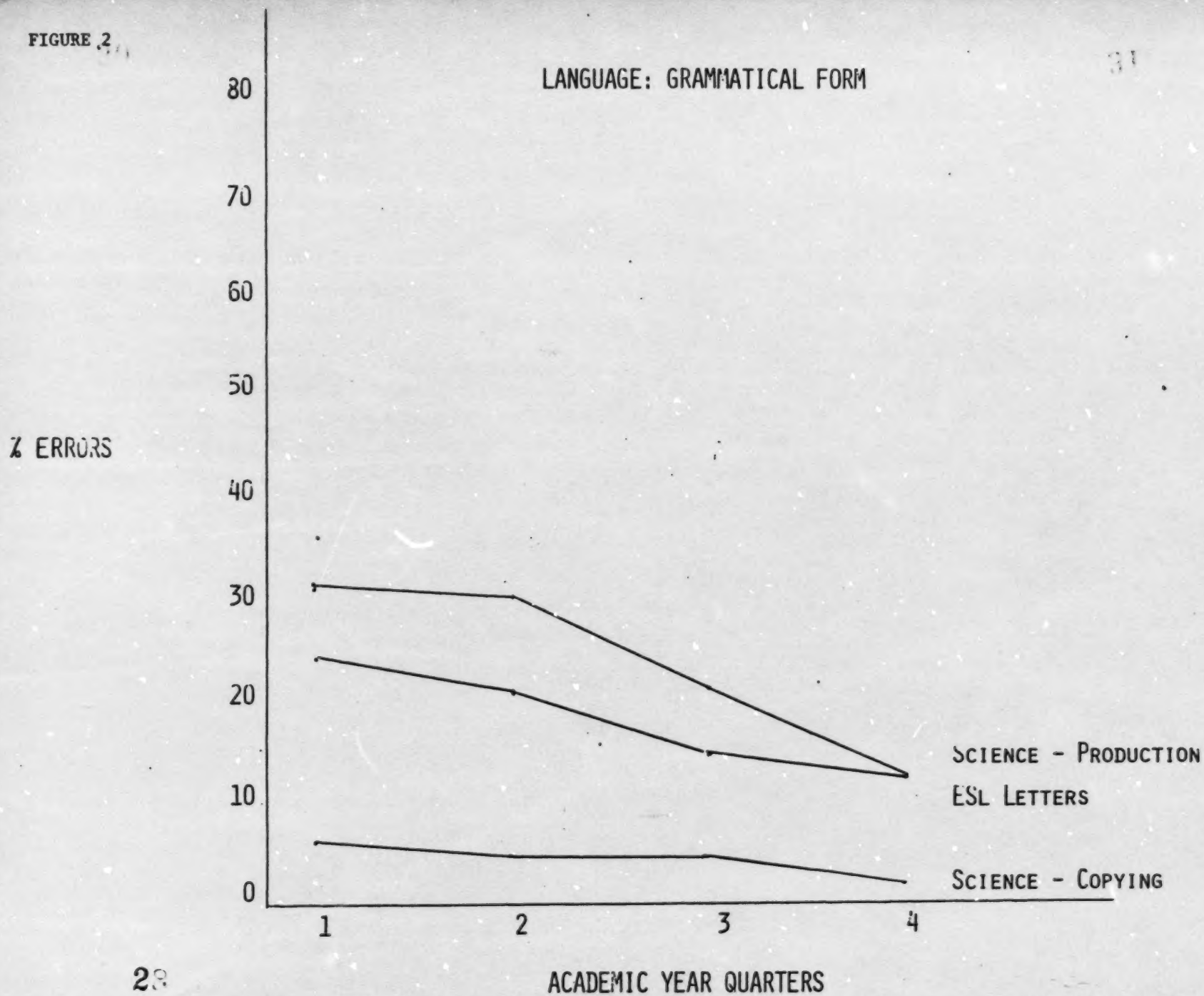


FIGURE 3

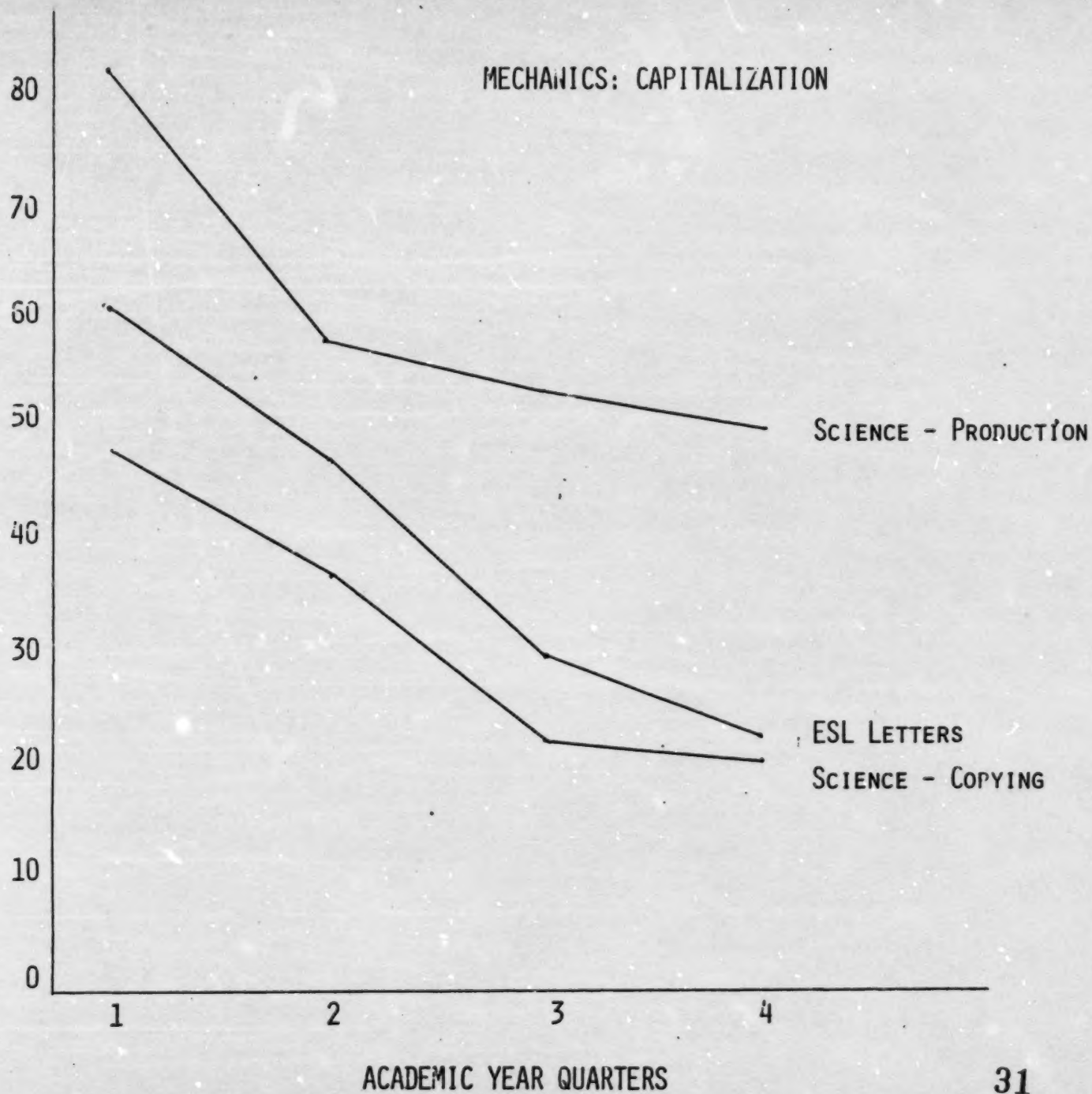


FIGURE 4

Z ERRORS

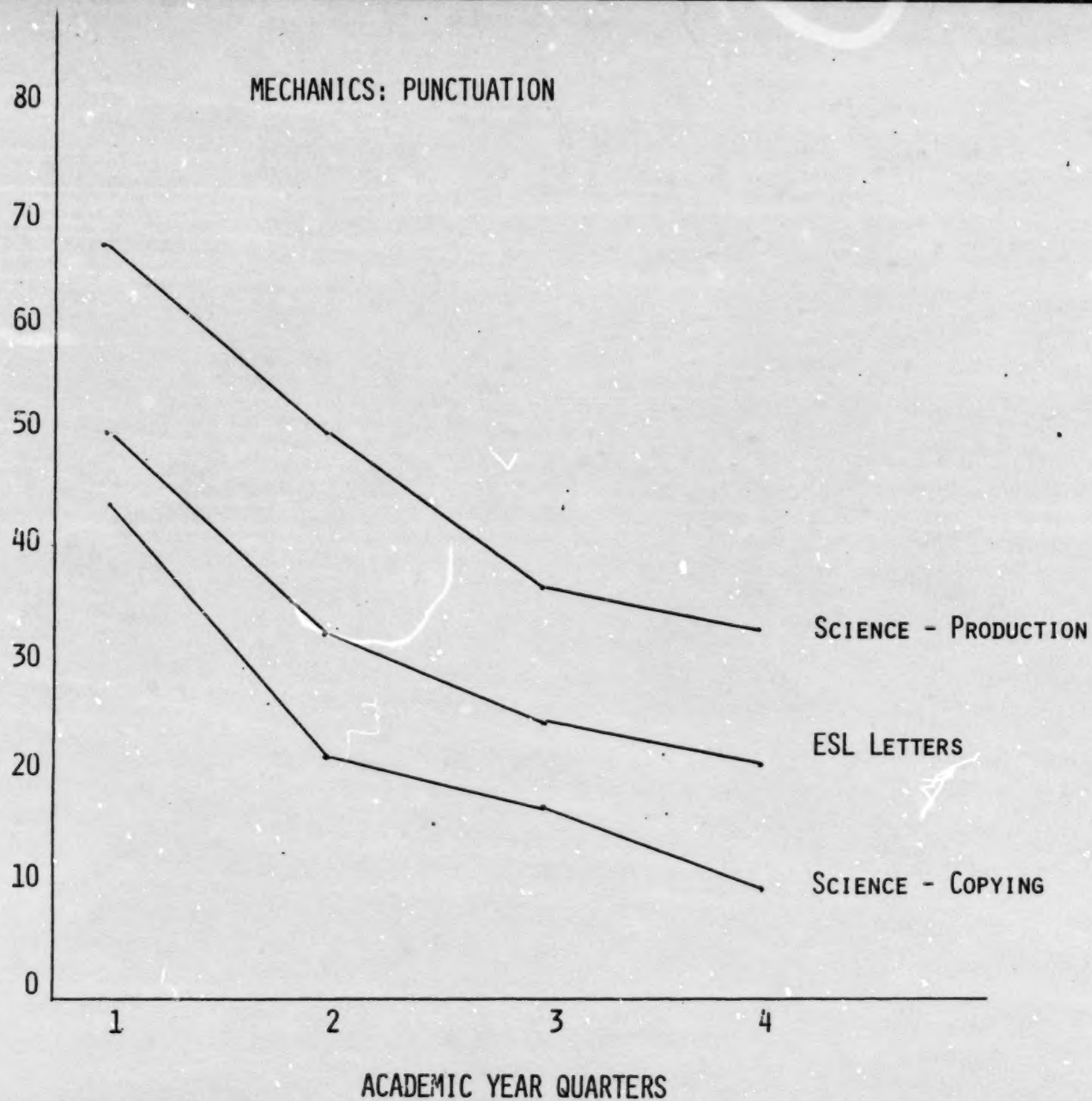


FIGURE 5

MECHANICS: SPELLING

% ERRORS

